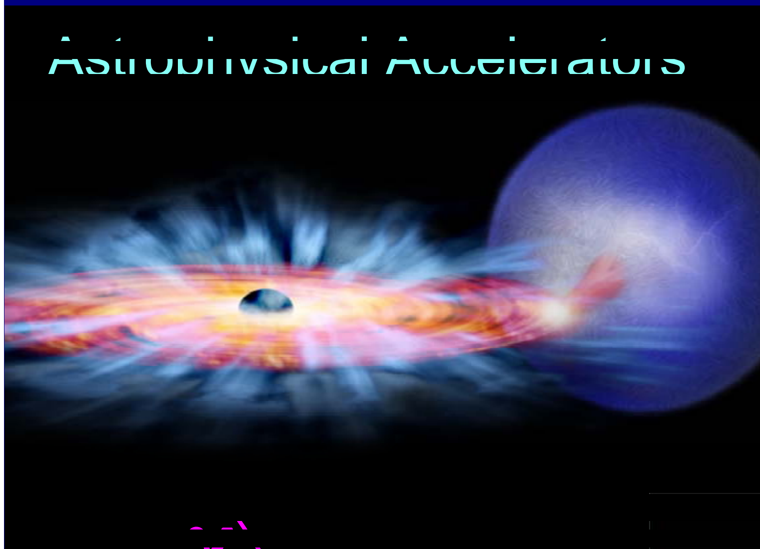
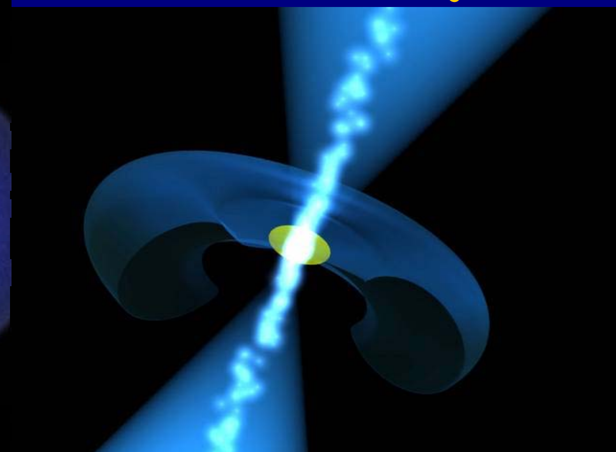
IceCube Neutrino Observatory

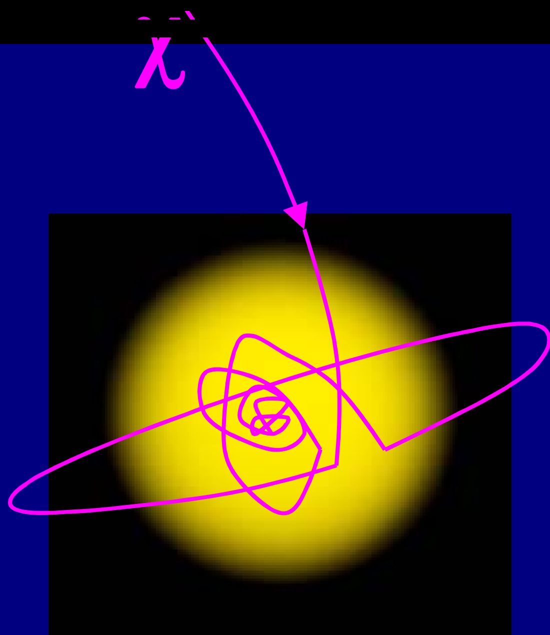
Jim Yeck
IceCube Project Director
University of Wisconsin

Why neutrino astronomy?

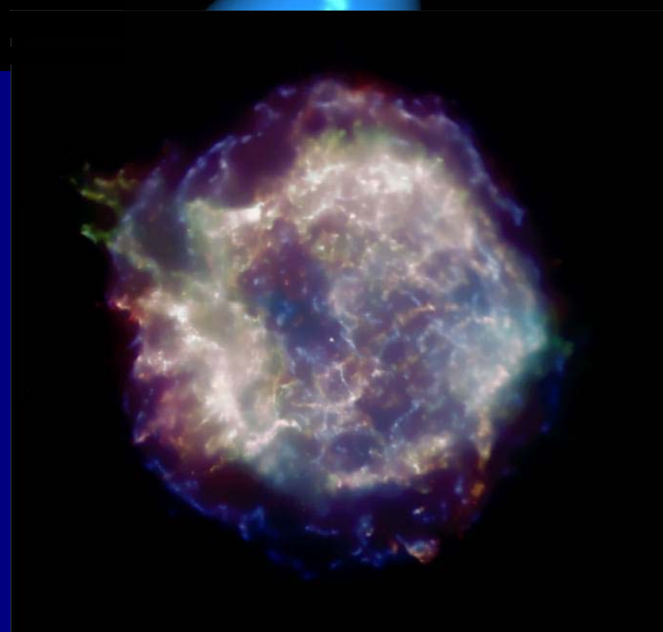


Accretion disk with jets





DM annihilation



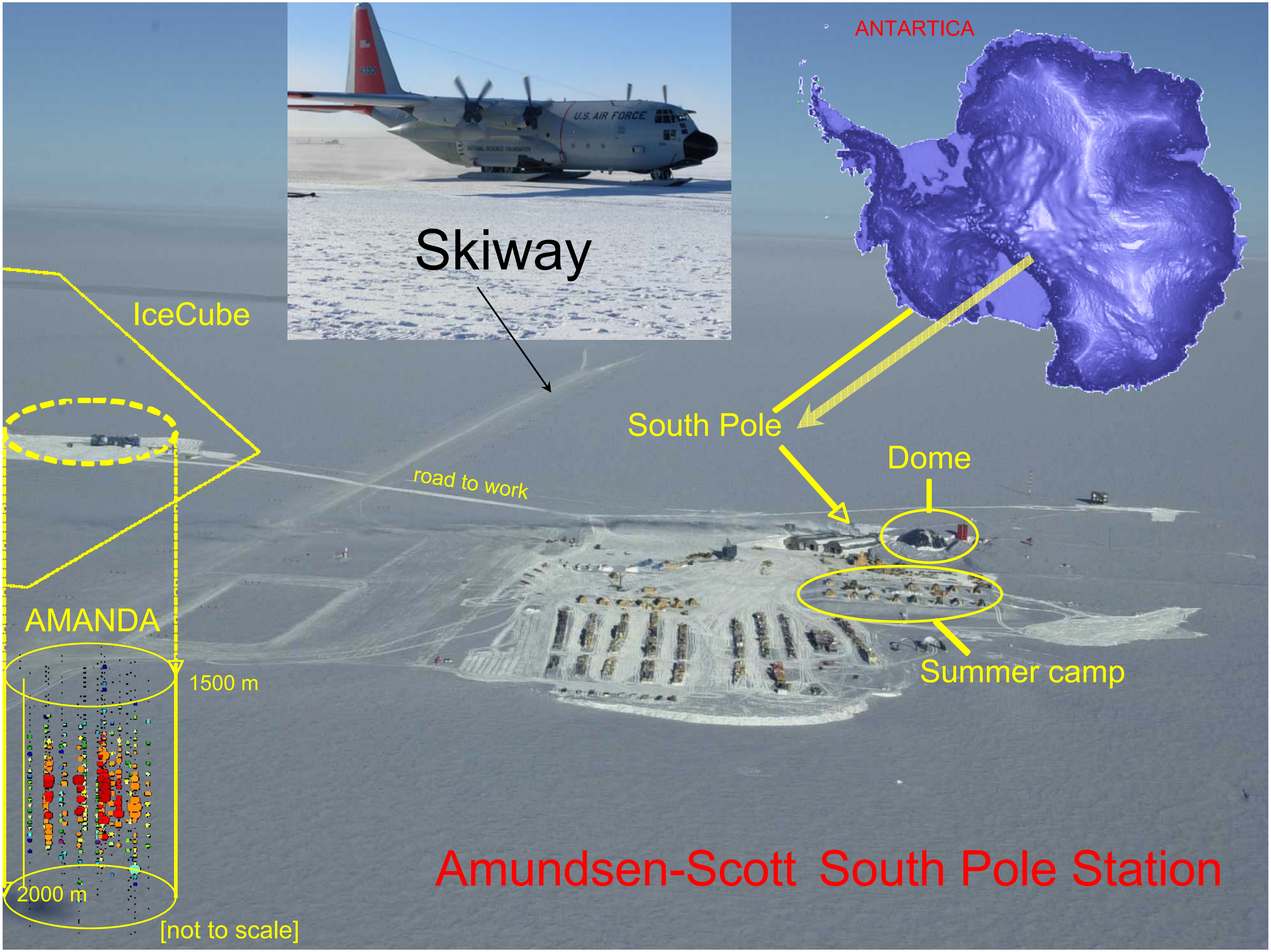
CasA Supernova Remnant in X-rays

Neutrinos allow for observation of 'hidden regions' of cosmic accelerators of high energy particles.

Black holes in active galaxies, pulsars,

Supernova explosions,

gamma ray bursts


ANTARTICA
Skiway
IceCube
South Pole
Dome
road to work
AMANDA
1500 m
Summer camp
2000 m
[not to scale]
Amundsen-Scott South Pole Station

The dome, the old station

New South Pole Station

Collaboration

http://icecube.wisc.edu

United states

- Univ Alaska, Anchorage
- UC Berkeley
- UC Irvine
- Clark-Atlanta University
- U Delaware / Bartol Research Inst
- University of Kansas
- Lawrence Berkeley National Lab
- University of Maryland
- Pennsylvania State University
- University of Wisconsin-Madison
- University of Wisconsin-RiverFalls
- Southern University, Baton Rouge

Europe

University Utrecht

- Uppsala University
- Stockholm University

- University of Oxford

- Universitat Libre de Bruxelles
- Vrije Universiteit Brussel
- Université de Mons-Hainaut
- Universiteit Gent

- Universität Mainz
- Humboldt Univ., Berlin
- DESY, Zeuthen
- Universität Dortmund
- Universität Wuppertal
- MPI Heidelberg
- RWTH Aachen

Japan

Chiba University

New Zealand

Univ. of Canterbury, Christchurch

IceCube Construction and Operations Organization

National Science Foundation

International Oversight & Finance Group

UW Leadership Team
Chair, J. Wiley

UW IceCube Center Support
- Accounting & Purchasing Services (shared with KRC), R. Paulos (A)
- Education & Outreach, E. Malkus
- Human Resources, T. Wipperfurth
- Information Technology, M. Mueller
- Resource Coordinator, D. Laitsch

IceCube Neutrino Observatory
- Principal Investigator, F. Halzen
- Director, J. Yeck
- Associate Director, A. Karle
- Associate Director, R. Paulos
- Software Coordinator, M. Merck
- Safety & QA Manager, M. Zernick

IceCube Collaboration & Collaboration Board
- Spokesperson, T. Gaisser
- Analysis Coordinator, G. Hill
- Executive Committee

Science Advisory Committee
Chair, M. Shaevitz

Trigger, Filter, Transmit Board
Chair, E. Blaufuss

Project Controls, Engineering & Polar Support — R. Paulos
- **Project Controls** — A. Peles
- **Engineering** — R. Paulos
- **Raytheon Polar Services Company** — S. Clapp

Drilling & String Installation — T. Hutchings
- **Drill** — A. Elcheick
- **String Installation** — T. Ham
- **Logistics** — T. Hannaford

Instrumentation — J. Haugen
- **Optical Modules** — J. Haugen
- **IceTop** — T. Gaisser
- **Cables/Special Devices** — J. Baccus

Data Infrastructure Construction — G. Sullivan
- **Data Acquisition System** — K. Hanson
- **Data Systems** — G. Sullivan
- **Verification & Commissioning** — D. Cowen
- **Pre-Operations** — J. Yeck

Detector Operations & Maintenance — K. Hanson
- **Run Coordination** — A. Goldschmidt
- **Operations & Maintenance** — M. Krasberg
- **DAQ/Online Processing** — J. Jacobsen
- **Monitoring** — I. Taboada

Computing Technology & Support — D. Schneider
- **Northern Data Center** — J. Richards
- **Network Security** — P. Wisniewski
- **Tier 0 (NPX) 2** — S. Barnet
- **South Pole System & Test System Maintenance** — K. Soundarapandian
- **Data Transfer** — C. McKenzie

Software & Data Processing — M. Merck (A)
- **Filtering & Software** — E. Blaufuss
- **Primary Data Processing** — M. Merck (A)
- **Data Integrity** — C. Rott
- **Monte Carlo Production** — K. Hultqvist
- **Calibration** — K. Woschnagg

Legend
- ——— Direction and Reporting
- - - - - Advice and Recommendations
- ······ Project Support
- (A) Acting

April 1, 2008

IceCube Detector

Deep Ice Detector

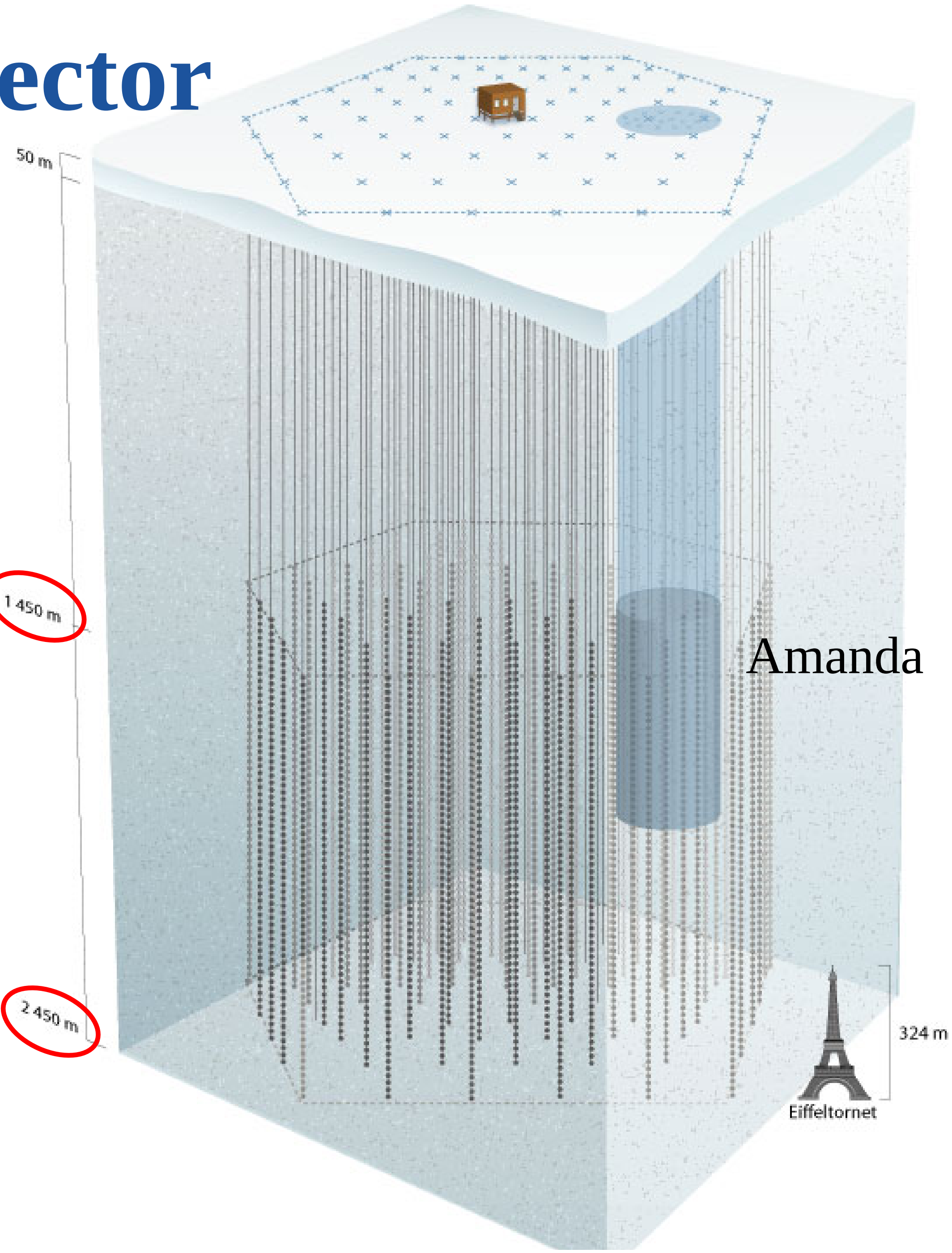
80 strings w/ 60 Digital Optical Modules
4800 Total Deep Ice DOMs
17 meters between DOMs
125 meters between strings
1 Giga Ton Detector
No single point failure in a string.

Dense "Low Energy" Core

19 String AMANDA Detector
677 Modules

IceTop Air Shower Array

80 Pairs of Cherenkov Ice Tanks
320 Total Air Shower DOMs
2 DOMs in each tank
10 meters between tanks



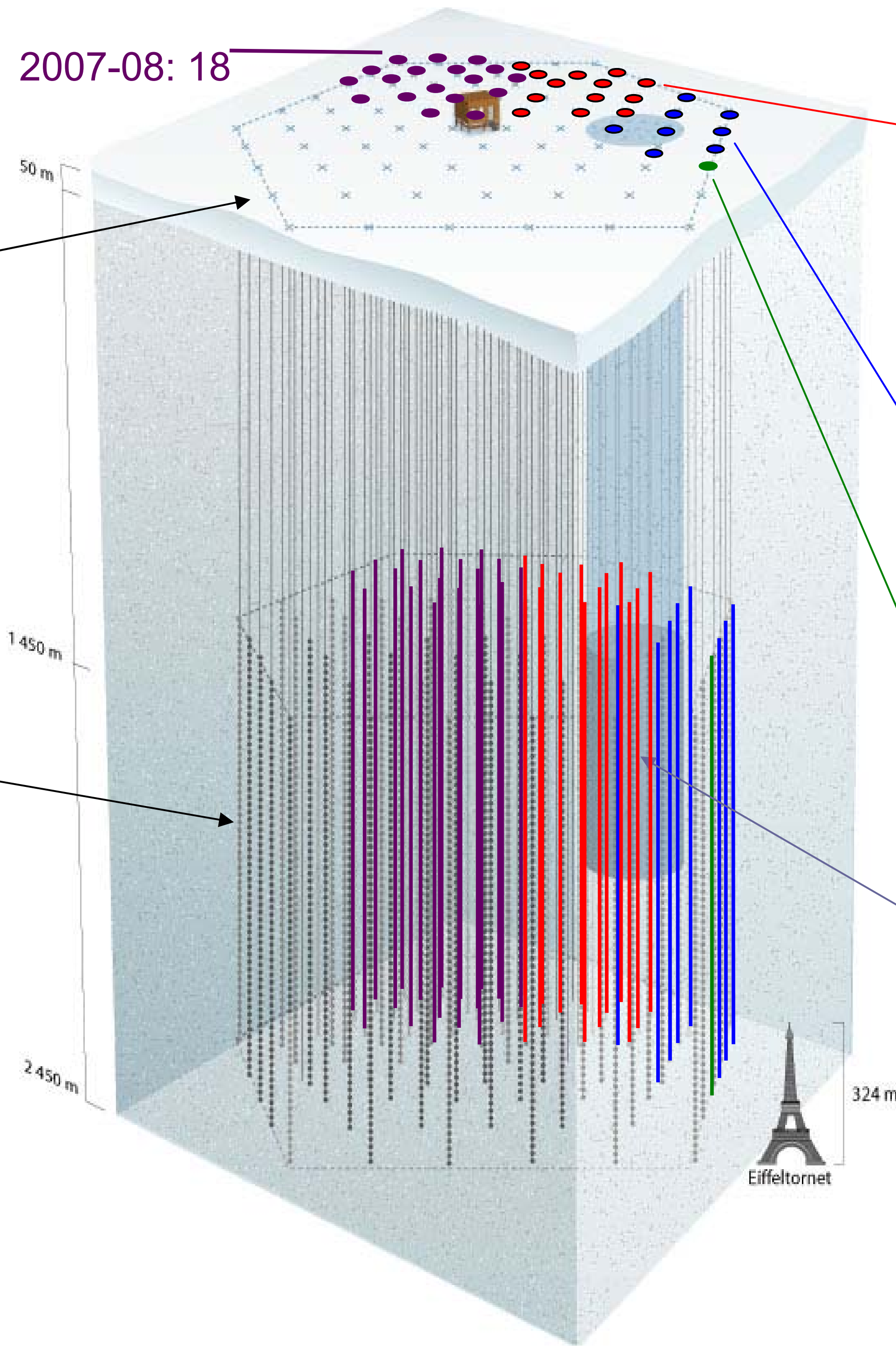
2007-08: 18

2006-07: 13 Strings

IceTop

80 Tanks Installed

total of 40 Strings



2005-06: 8 Strings

InIce

40 Strings Installed

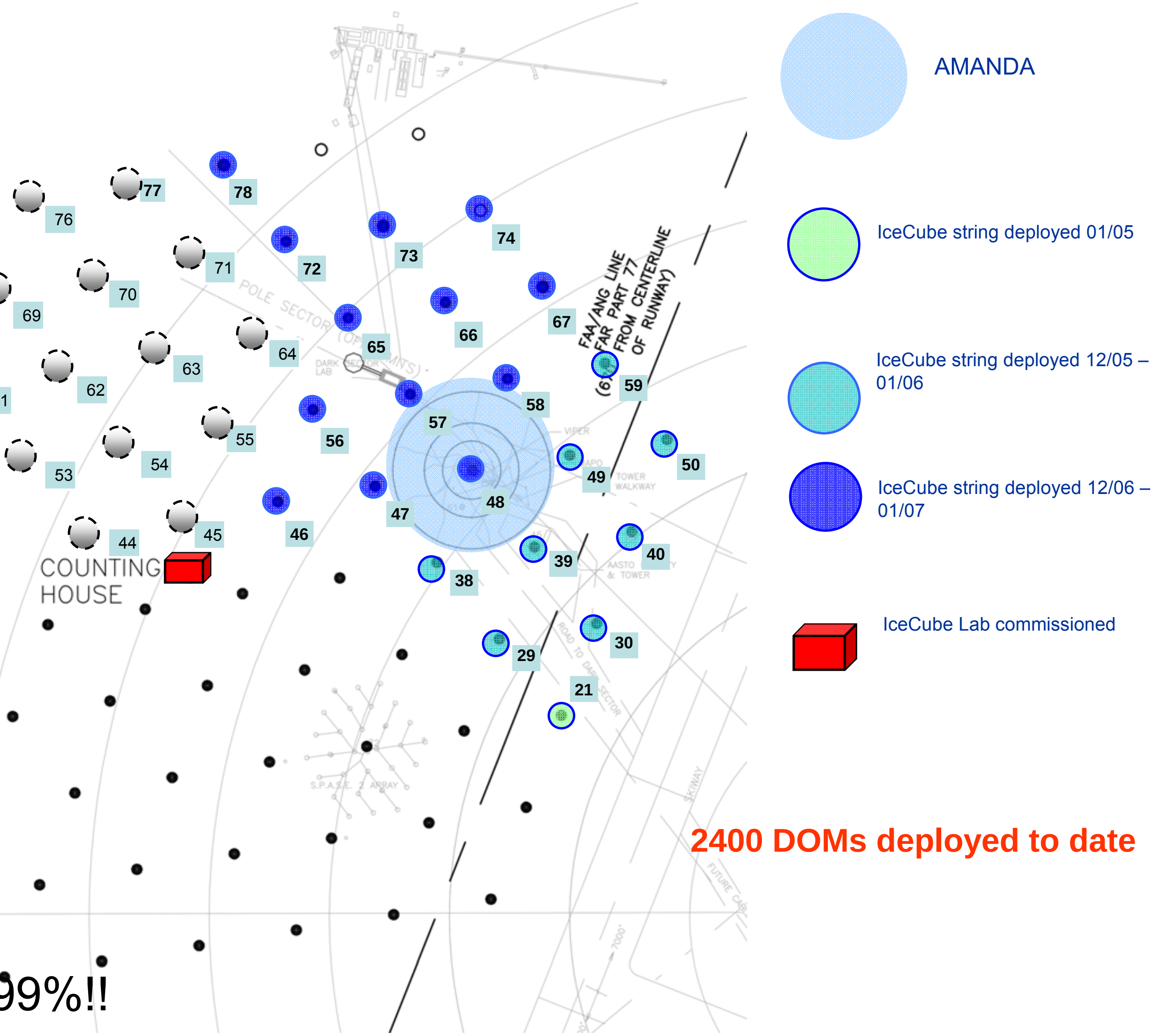
2004-05 : 1 String

first data 2005
upgoing muon 18. July 2005

AMANDA
19 Strings
677 Modules

2005-2008 configurations

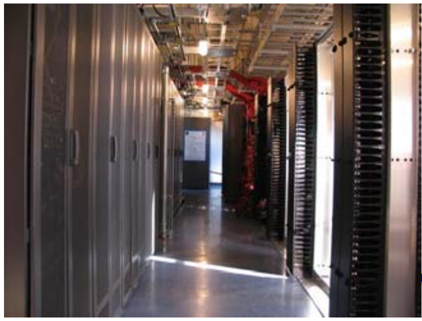
1+ 9 + 13 =
22 strings (IC22)
to date
+26 IceTop
stations



2400 DOMs deployed to date

This season:
18 more strings(IC40)
+ 40 IceTop stations
2011: 80 strings

Survival rate of DOMs 99%!!



Original Detector Baseline

- 70 vertical strings plus surface stations
- 4,480 Digital Optical Modules (DOM)
  - 60 DOM/string spaced between 1450 and 2450 meters
  - 2 DOM/surface tank and 2 tanks at each surface location
- Instrumented volume of ~1 km^3 of ice
- Software and computing required to commission and operate the detector

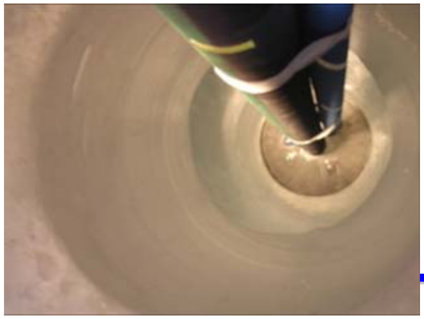
Cost & Schedule Baseline

		Baseline (Hartill 02/04)		Current (02/08)		
Cost:	TPC	$271.8 million		$276.6 million		
	NSF	$242.1	“	$242.1	“	*unchanged*
	Foreign	$ 29.7	“	$ 34.5	“	
Earned Value:		-		$215.5	“	(82%)
Contingency:		$40 million (22%)		$15 million		(26%)

Most of the Technical Risk Retired

Schedule: 4th Quarter (Q4), 2010 → Q2, 2011

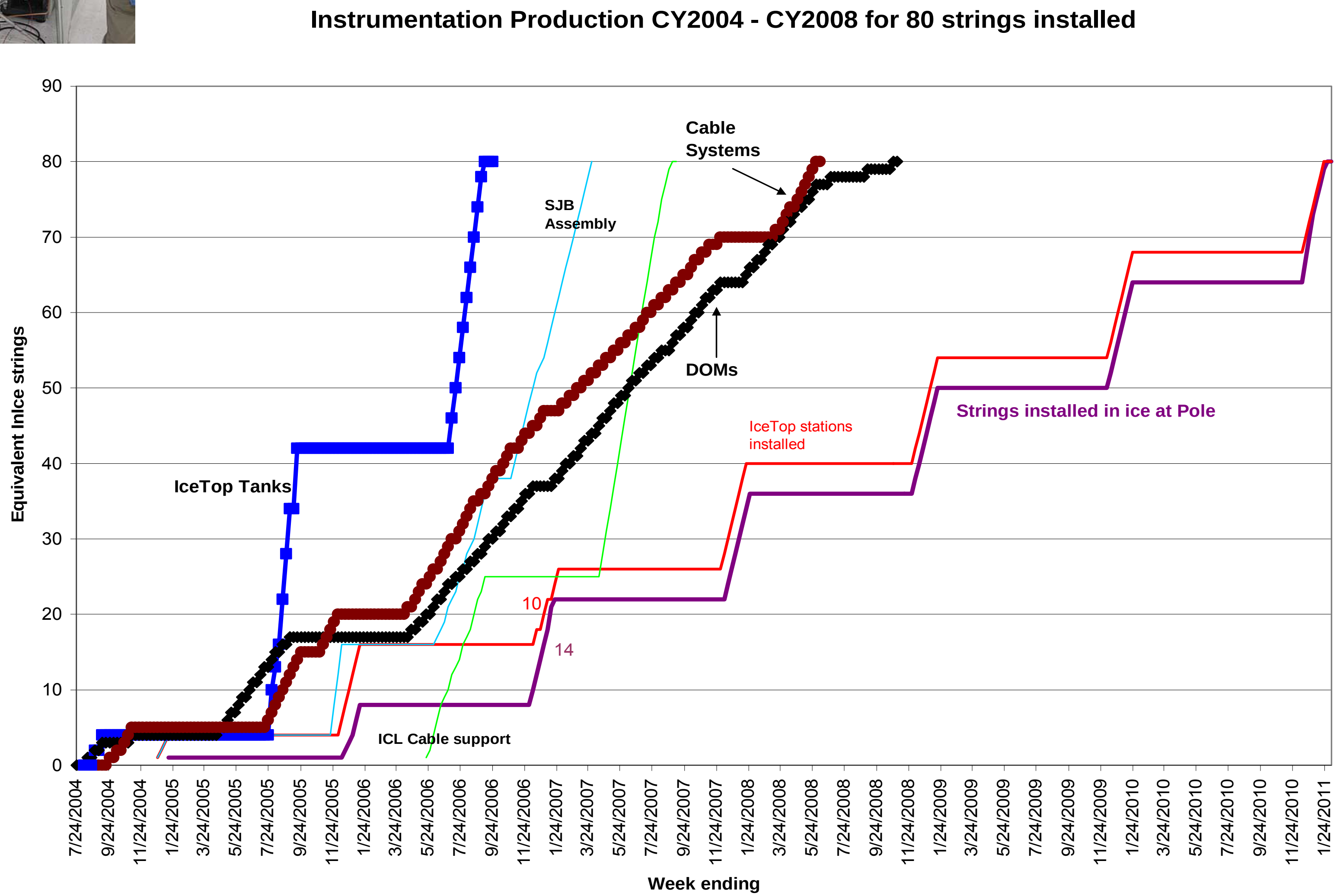
	Baseline	Current
Schedule:	4th Quarter (Q4), 2010	Q2, 2011



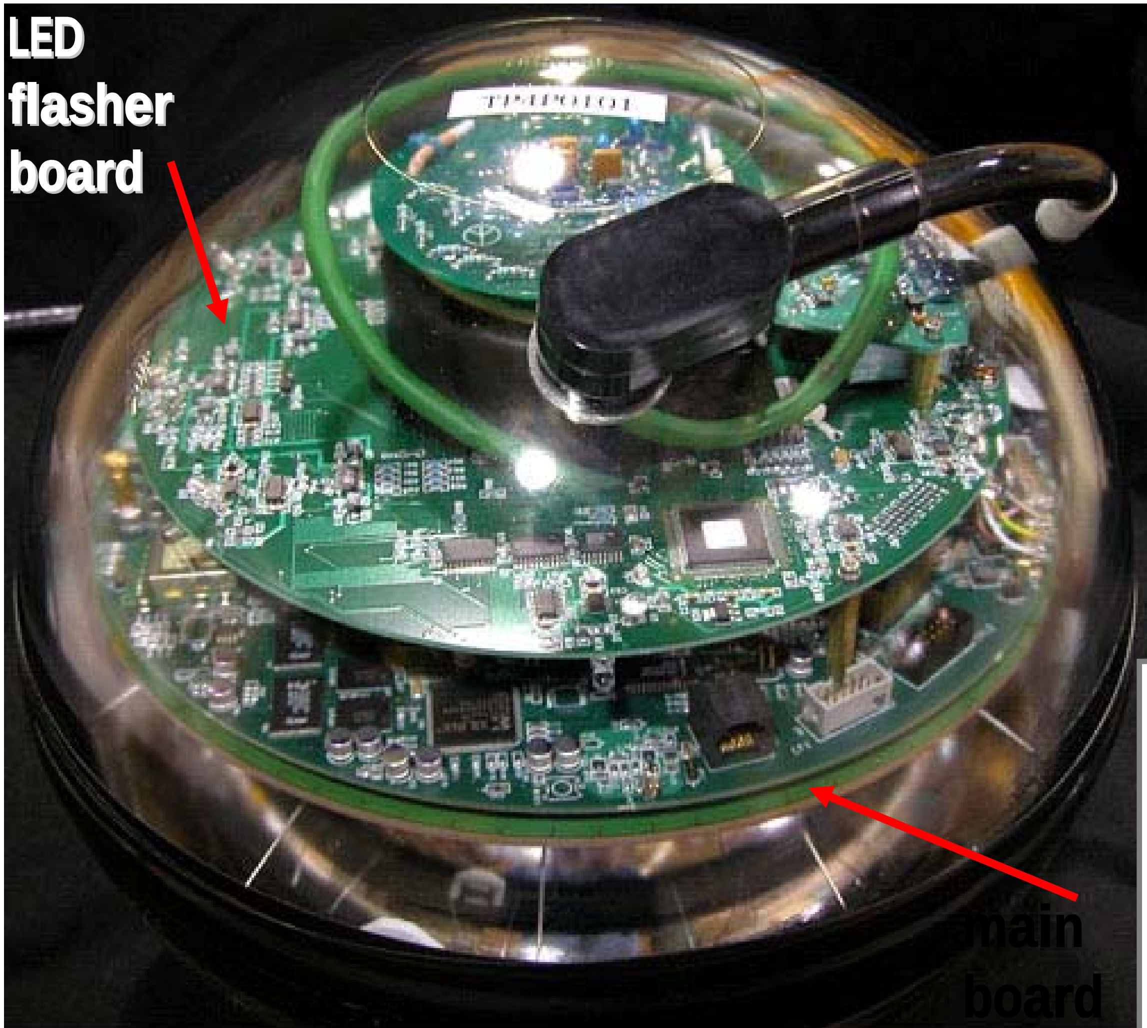
Construction Strategy

- Construction Schedule Constraints
  - South Pole construction season limited to the austral summer
  - Limits on the number of cargo and fuel flights to the South Pole
  - Limits on the number of people that can be supported at South Pole
- Critical schedule activity is the safe drilling of holes in the ice
- Maximize the instrumentation that can be installed each summer
  - Ensure that installation is not limited by instrumentation
- Provide for concurrent detector construction and operations

Instrumentation Production



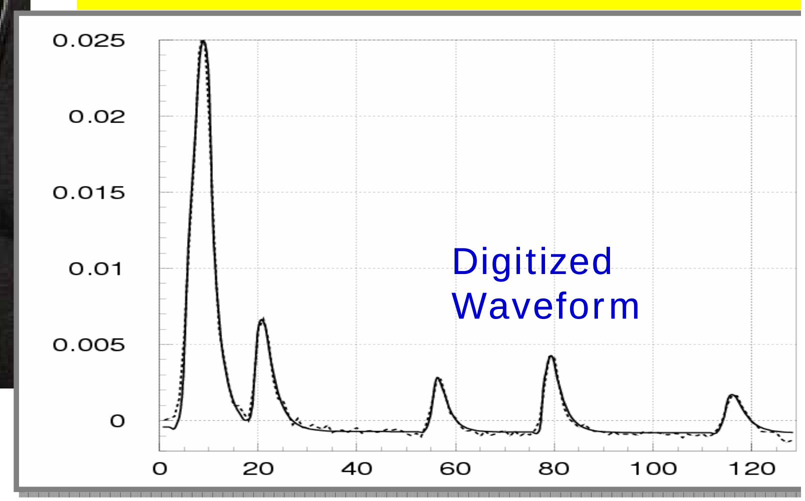
Digital Optical Module (DOM)



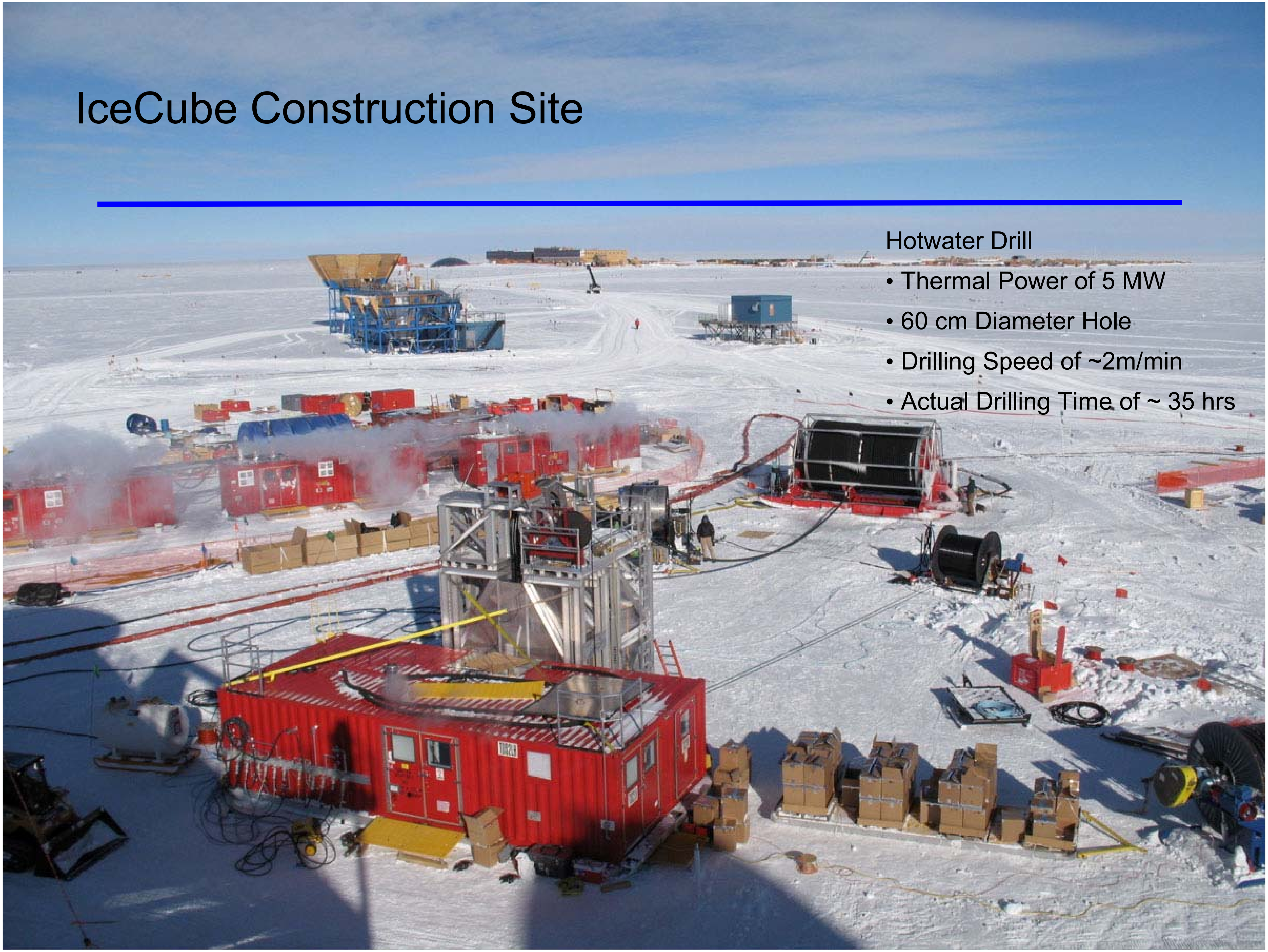
PMT: 10 inch Hamamatsu
Power consumption: 3 W
Digitize at 300 MHz for 400 ns with custom chip
40 MHz for 6.4 μs with fast ADC
Dynamic range 200pe/15 nsec

Send all data to surface over copper
2 sensors/twisted pair.
Flasherboard with 12 LEDs
Local HV

Clock stability: $10^{-10} \approx 0.1$ nsec / sec
Synchronized to GPS time every $\approx$10 sec
Time calibration resolution = 2 nsec



IceCube Construction Site

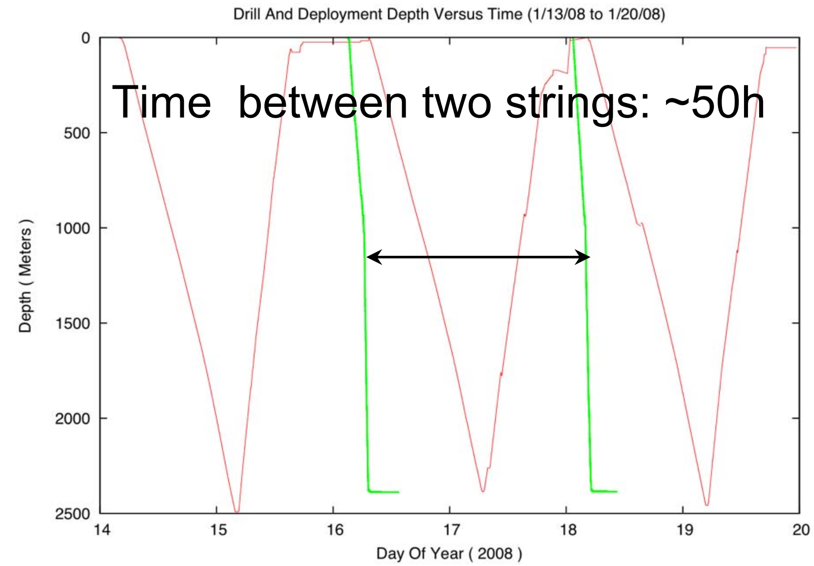


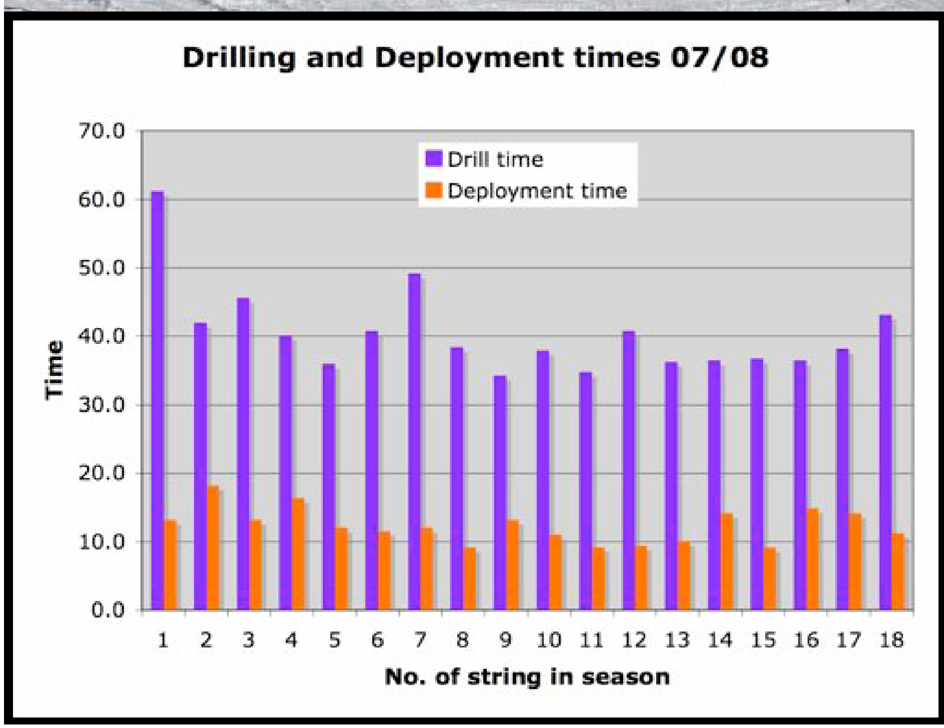
Hotwater Drill

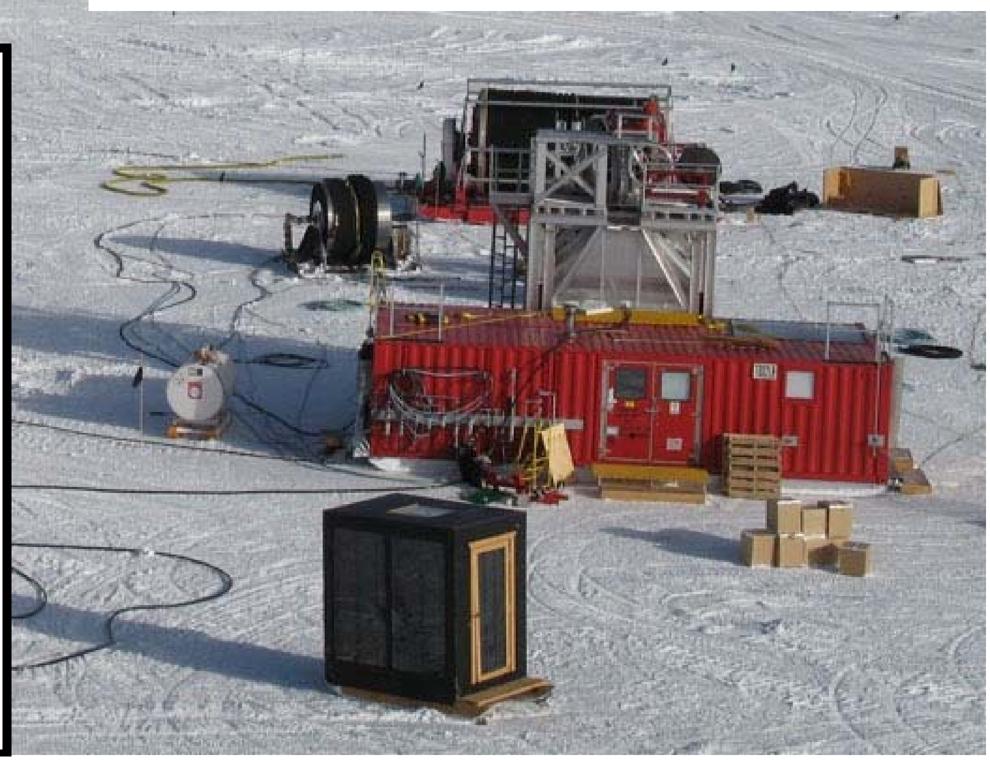
- Thermal Power of 5 MW
- 60 cm Diameter Hole
- Drilling Speed of ~2m/min
- Actual Drilling Time of ~ 35 hrs

Drilling

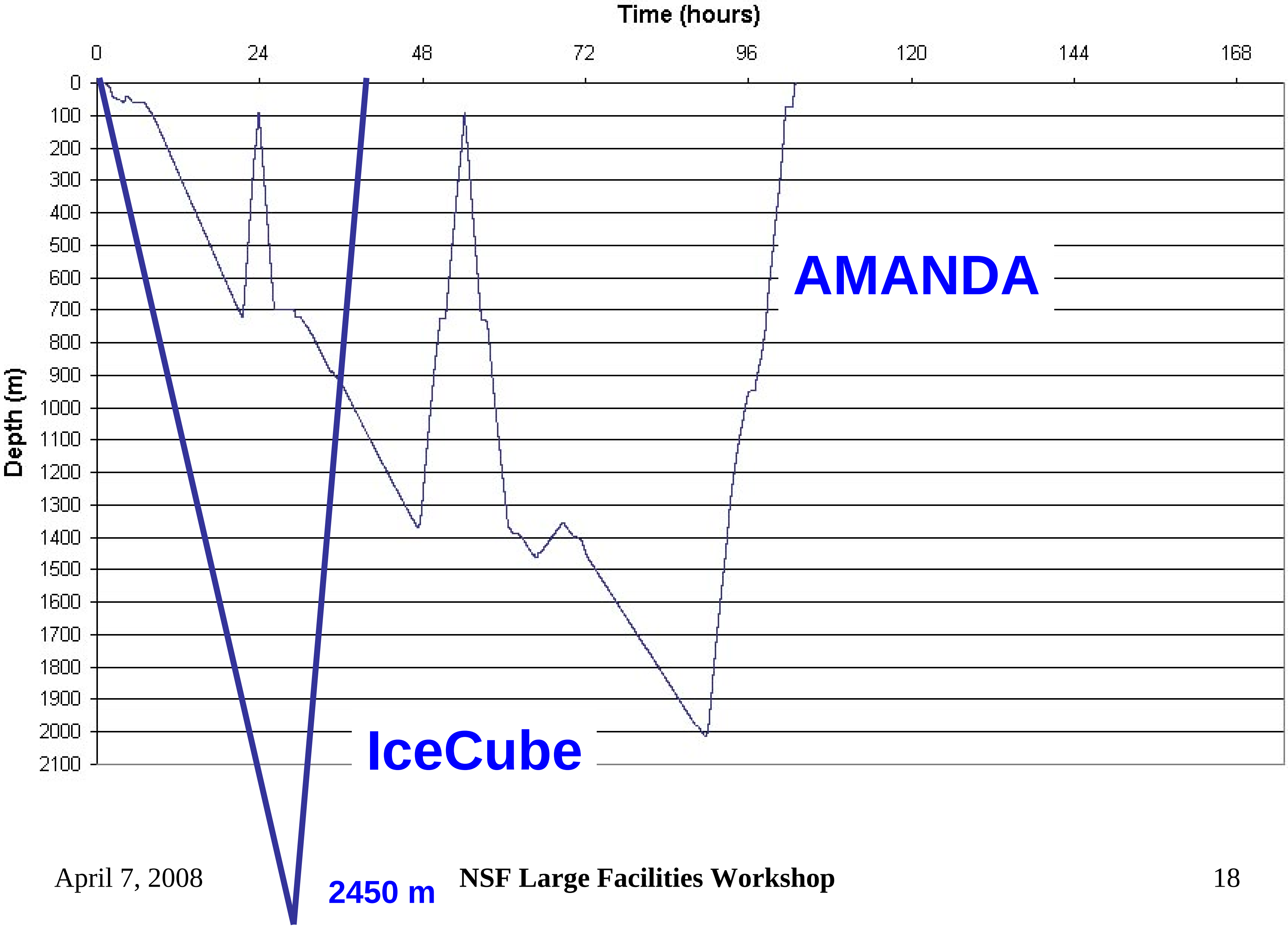

Drilling camp


Drill And Deployment Depth Versus Time (1/13/08 to 1/20/08)
Time between two strings: ~50h
Depth (Meters)
0
500
1000
1500
2000
2500
14
15
16
17
18
19
20
Day Of Year (2008)


Drilling and Deployment times 07/08
Drill time
Deployment time
Time
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
No. of string in season



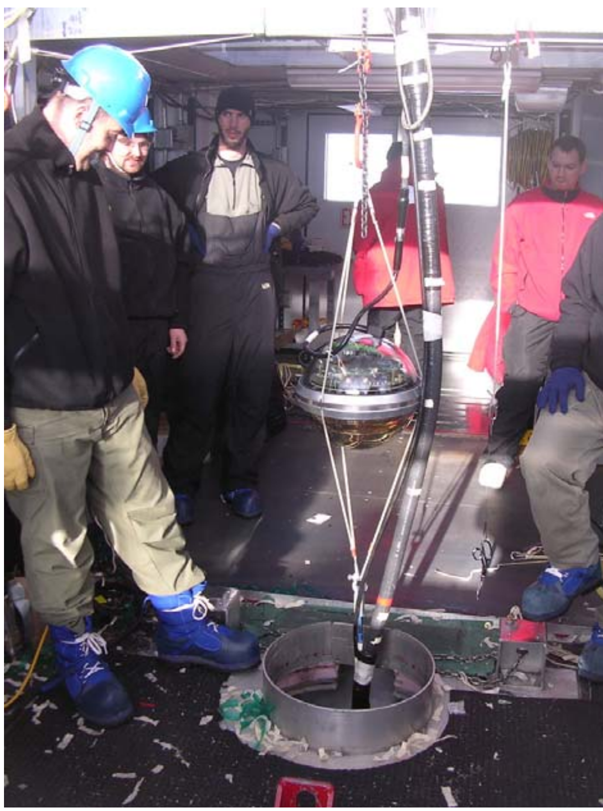
AMANDA vs. IceCube Drilling

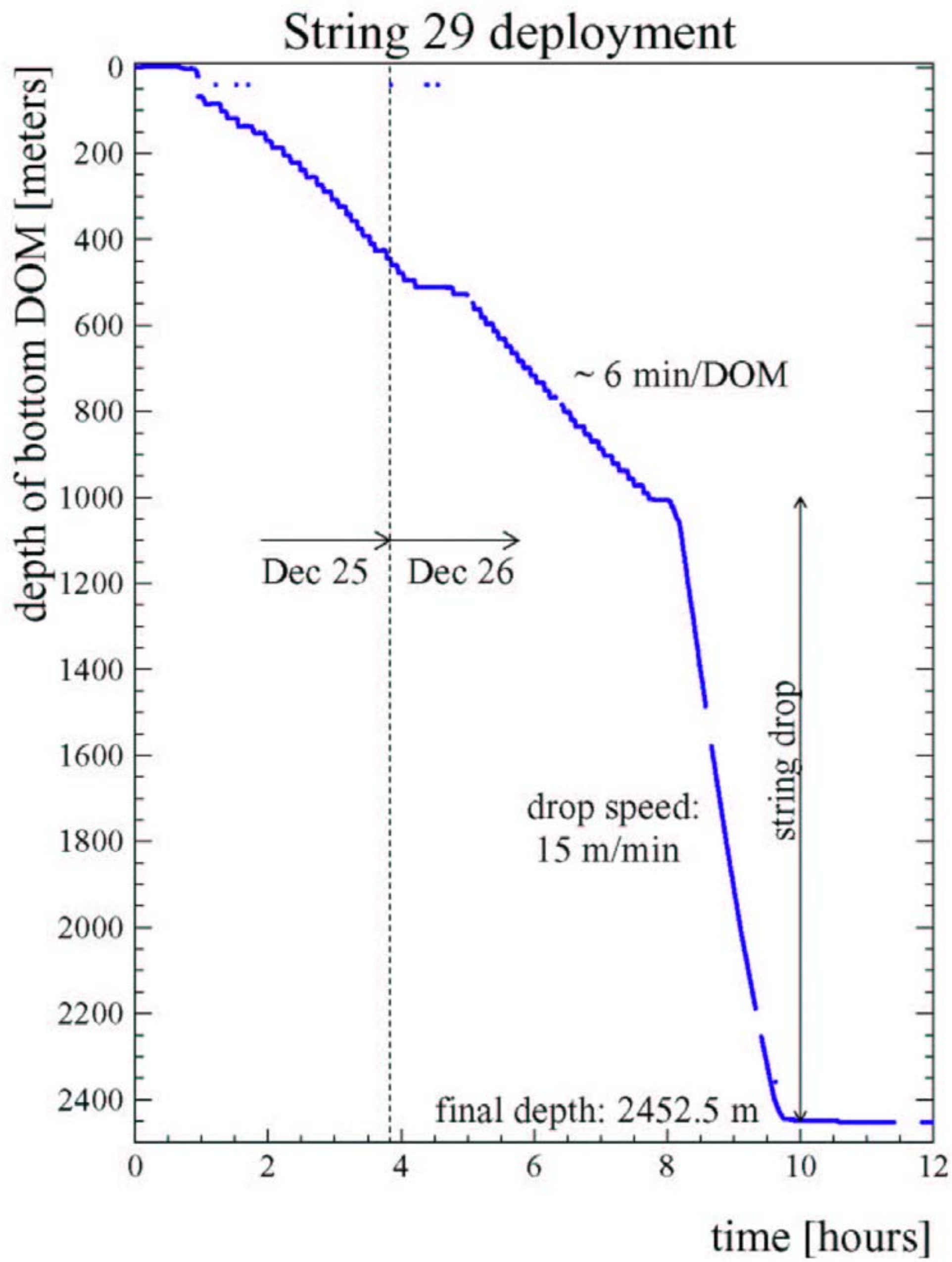


String cable 2500 m

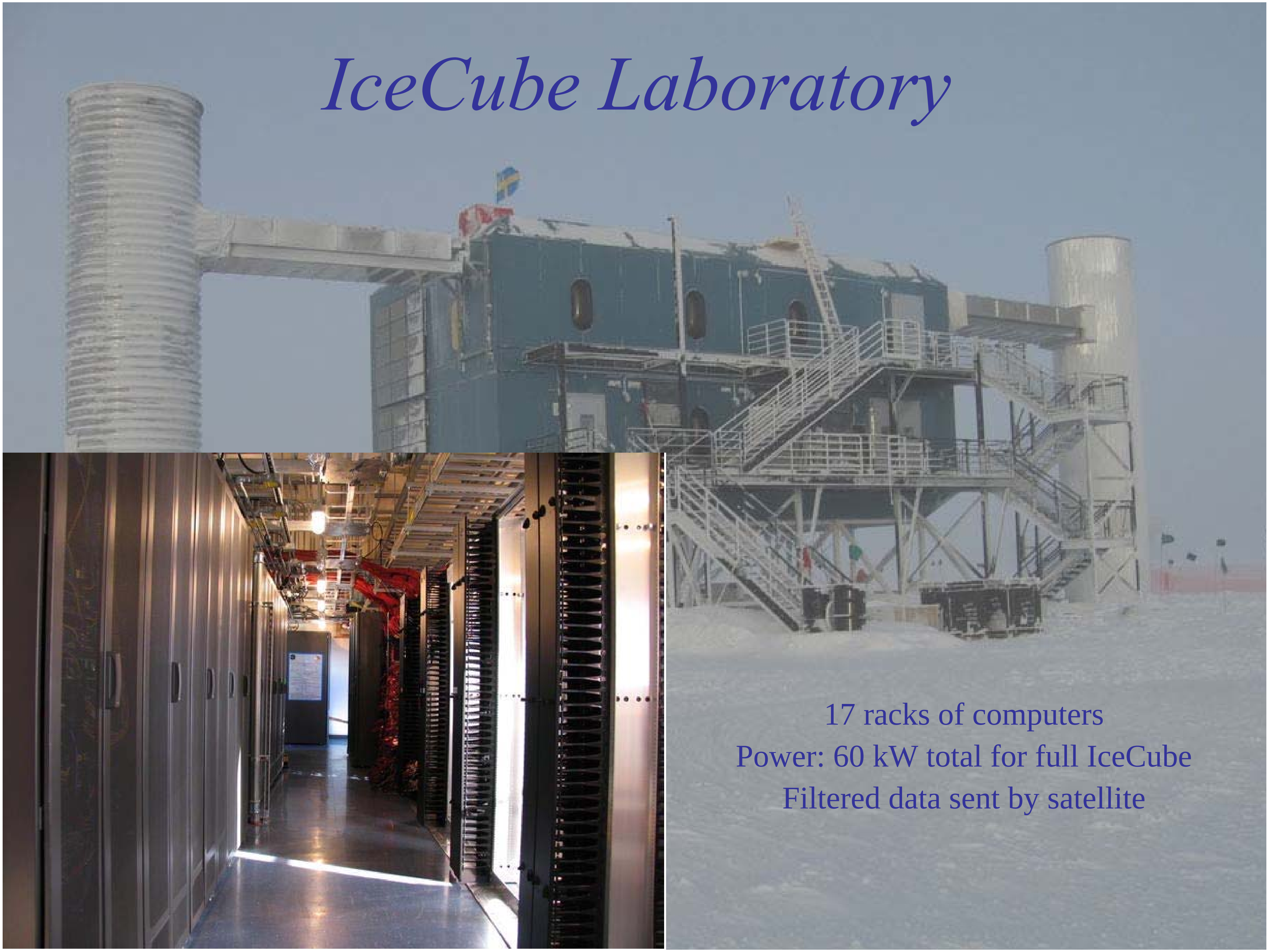
Weight ~6 tons

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.



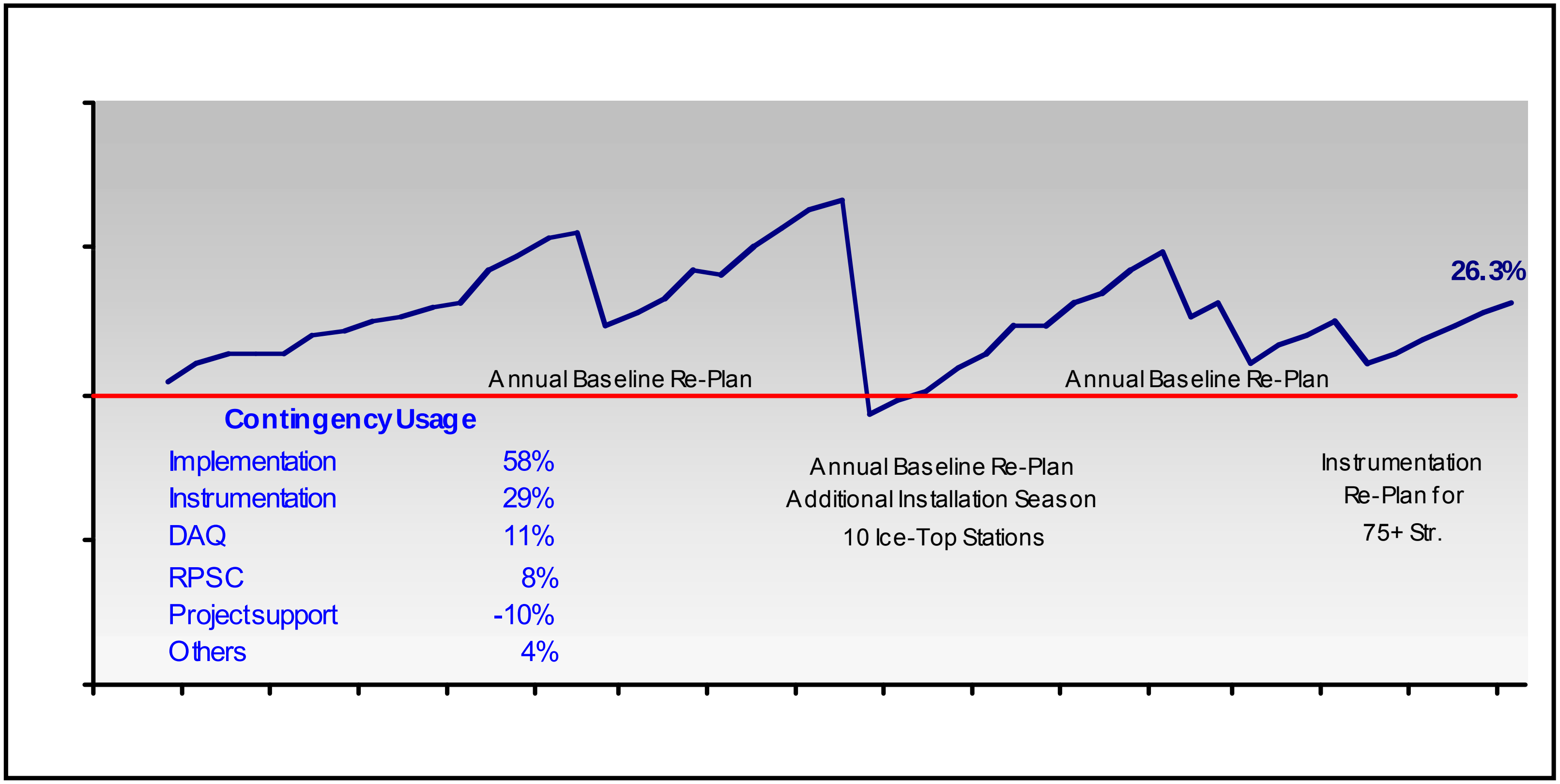


IceCube Laboratory

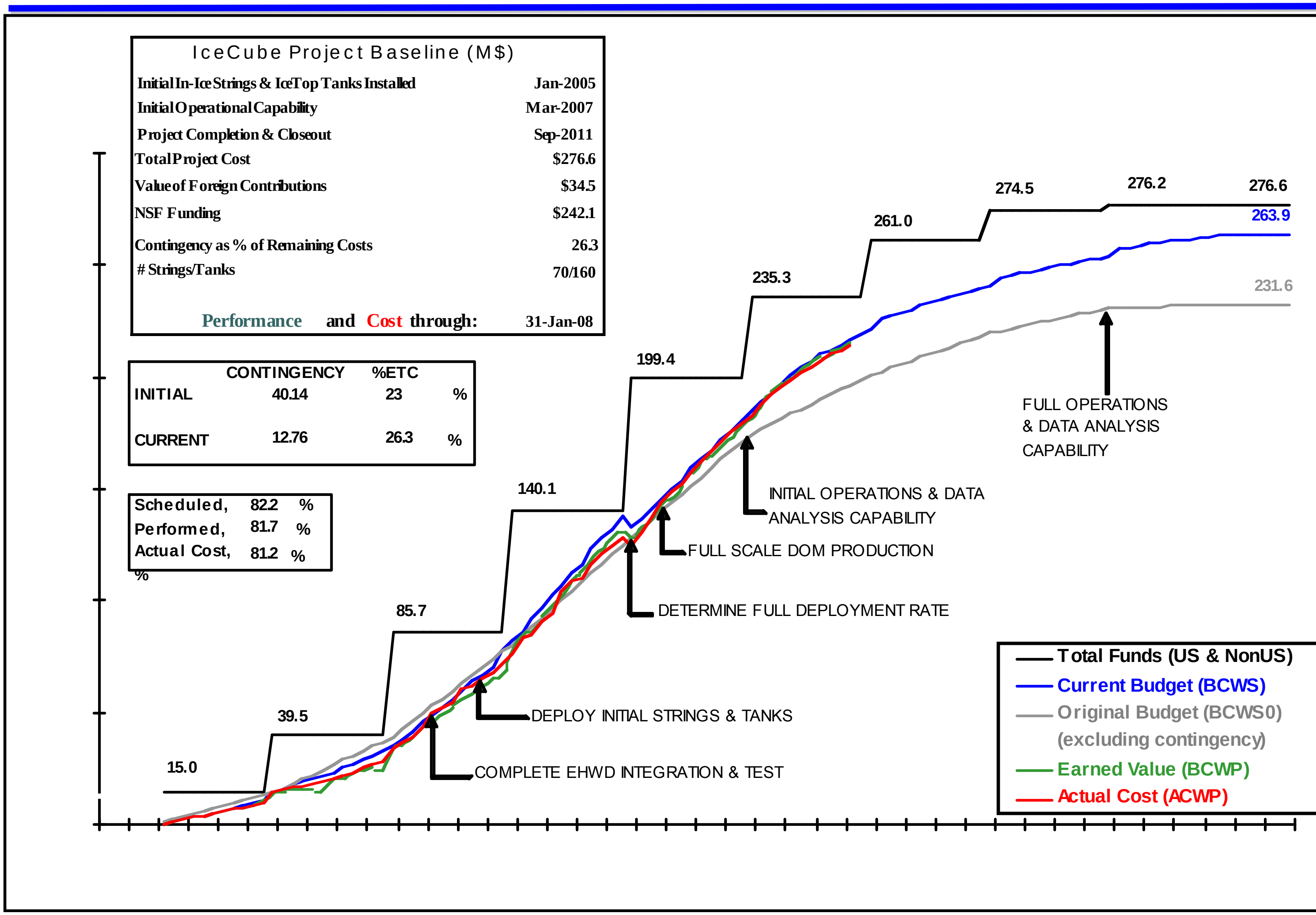


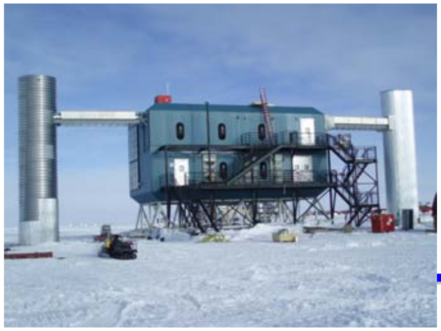
17 racks of computers
Power: 60 kW total for full IceCube
Filtered data sent by satellite

Contingency (% of Work-to-Go)



Cost & Schedule Performance

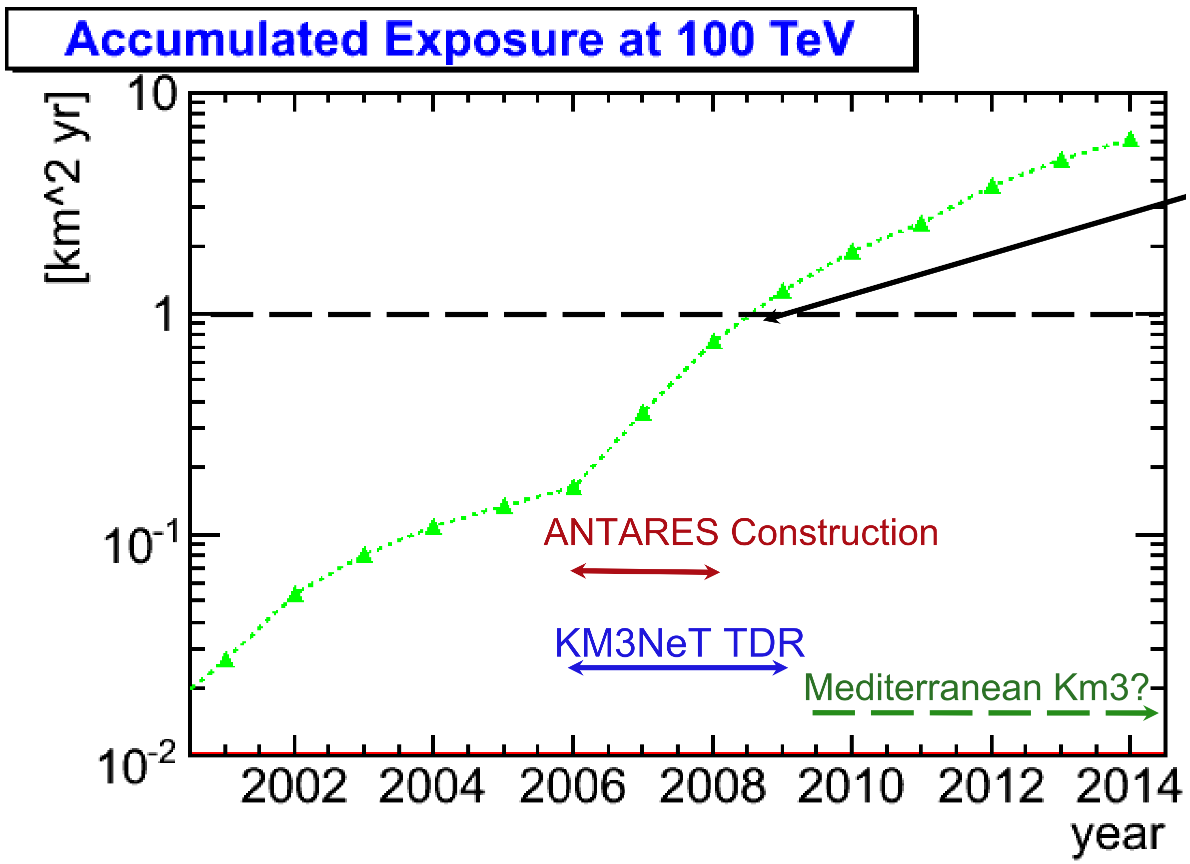




Summary

- Construction project is ~82% complete (earned value)
  - Confident in the quality of completion plans
  - Conservative baseline plan for additional drilling years
  - Materials and labor costs are well understood
  - Continuous attention to safety performance
- Operations formally underway
- Restoring strings as originally planned
  - Plans in place for 80 Strings/IceTop Stations
  - Plan to replace AMANDA with 6+ Strings

Accumulated Exposure



IC40: Science Run starts in Apr 2008

Effective area for muons at 100 TeV

IceCube Challenges

- NSF's Limited Infrastructure and Experience w/ Large Facilities
  – Limited experience in "stewardship" role
  – Internal processes developed to meet different needs, typically small grants
  – Operations and transition needs not developed in advance (start-up/ops)
- Public University Infrastructure and Management
  – Business and human resource systems designed to meet different needs
  – Schedule imperative not a traditional motivator
- Detector Size and Collaboration Complexity
  – Large extrapolation from AMANDA (prototype) to IceCube detector
  – Increase in number of institutions and dependencies

IceCube Opportunities

- USAP Infrastructure and Support
  - Established site and supply chain (NSF, Raytheon, USAF, NYANG)
- University of Wisconsin Commitment and Infrastructure
  - Management support and overhead resources
  - Physical Sciences Laboratory (PSL) staff and facilities
  - Willingness to adapt university systems to meet large project needs
- Instrumentation production in 3 locals - U.S., Germany, Sweden
- Annual Feedback Loop - seasonal goals vs. accomplishments
- Early Operations and Research
  - Opportunity to address detector performance and long term support issues

IceCube Experience

- Construction cost baseline set realistic goals
  - Original scope reduced from 80 to 70 strings plus 20% contingency
  - Included plan for early start of operations
- NSF
  - NSF collaborated with UW to find ways to best support the project
    - Dedicated IceCube Project Officer
    - Annual Peer Reviews and Action Tracking
  - Construction funding secure and predictable
  - Operations and research funding more uncertain
- UW Resources and People
  - University leadership involvement critical at key junctures
  - Experienced personnel essential to project success

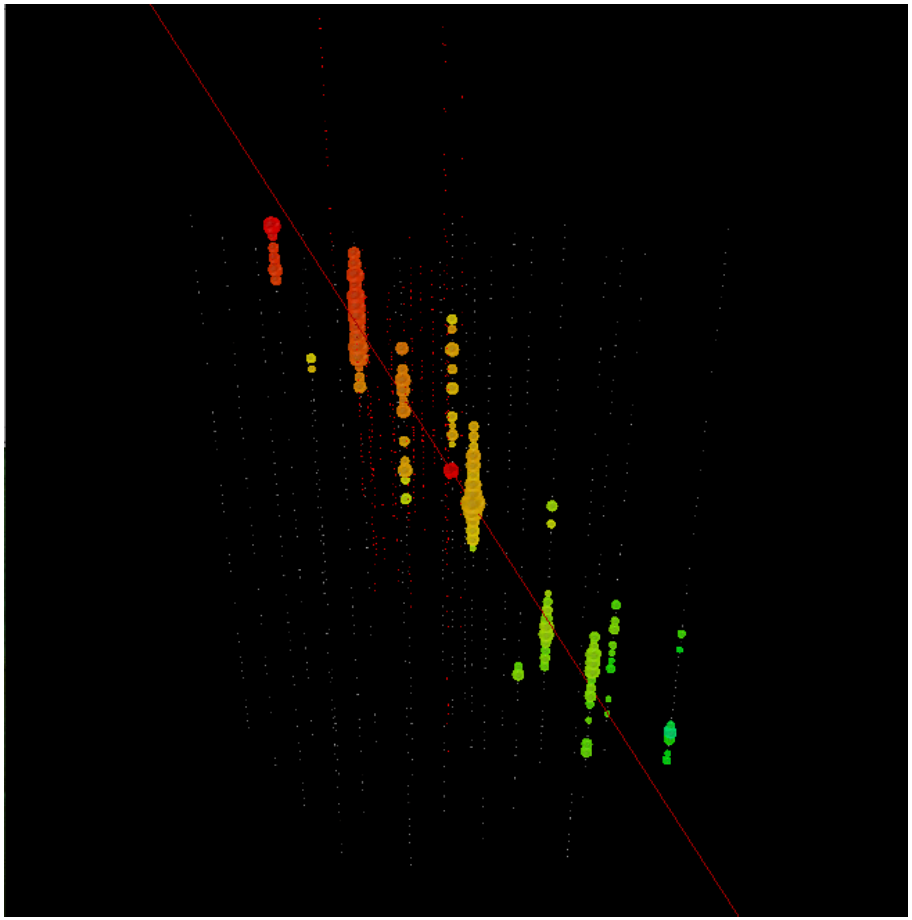
General Observations

- Ingredients to Success
  - Strong host role
  - Populate the organization with high quality people
  - Project & Collaboration Leadership
    - Makes decisions - seeking consensus whenever possible
    - Serves as an umbrella to the project team
    - Manages expectations and communicates plans and results
    - Develops strategies and revises goals as needed
  - Establish realistic project goals
  - Maintain credibility with stakeholders
  - Seek collective ownership of problems and solutions

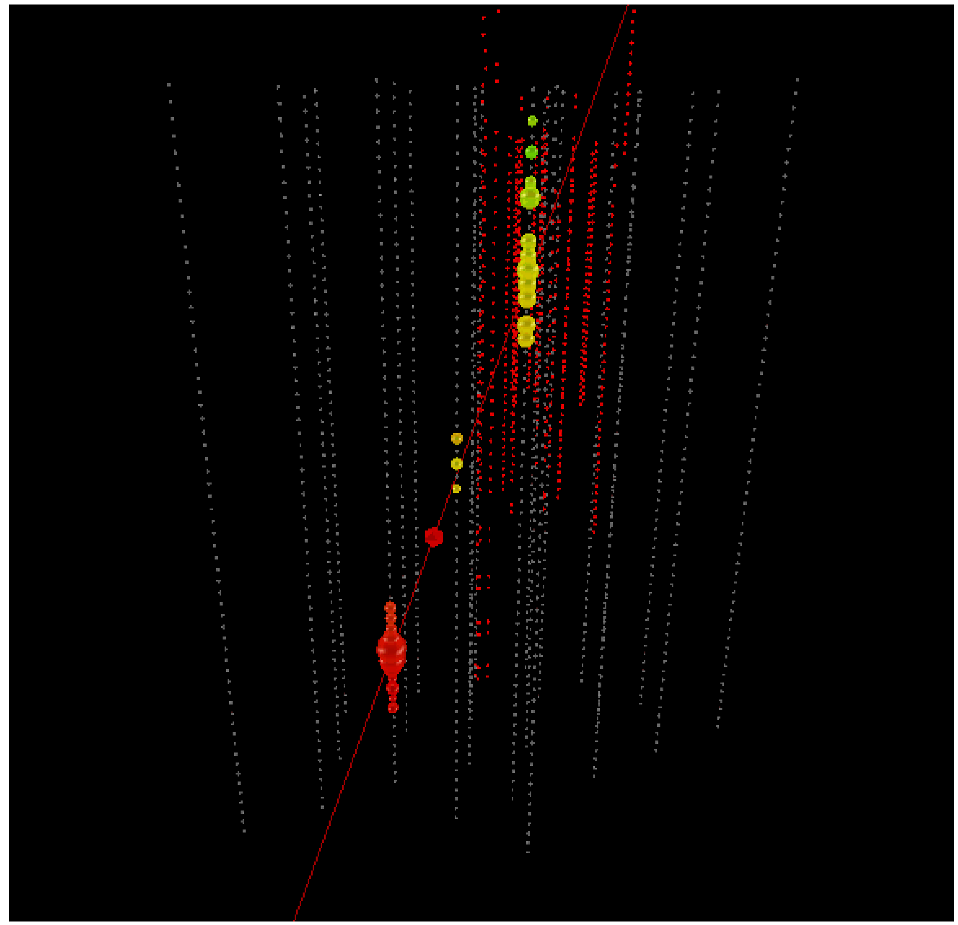
IC22 Events

(Red hits = early; yellow/green/blue = later)

IceCube DOM locations blue, AMANDA OM locations red



Downward cosmic-ray event ("muon bundle")



Upward candidate ν event

IC40 Event

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.